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Twenty-Year Growth of Thinned and Unthinned Ponderosa Pine in the Methow Valley of Northern Washington

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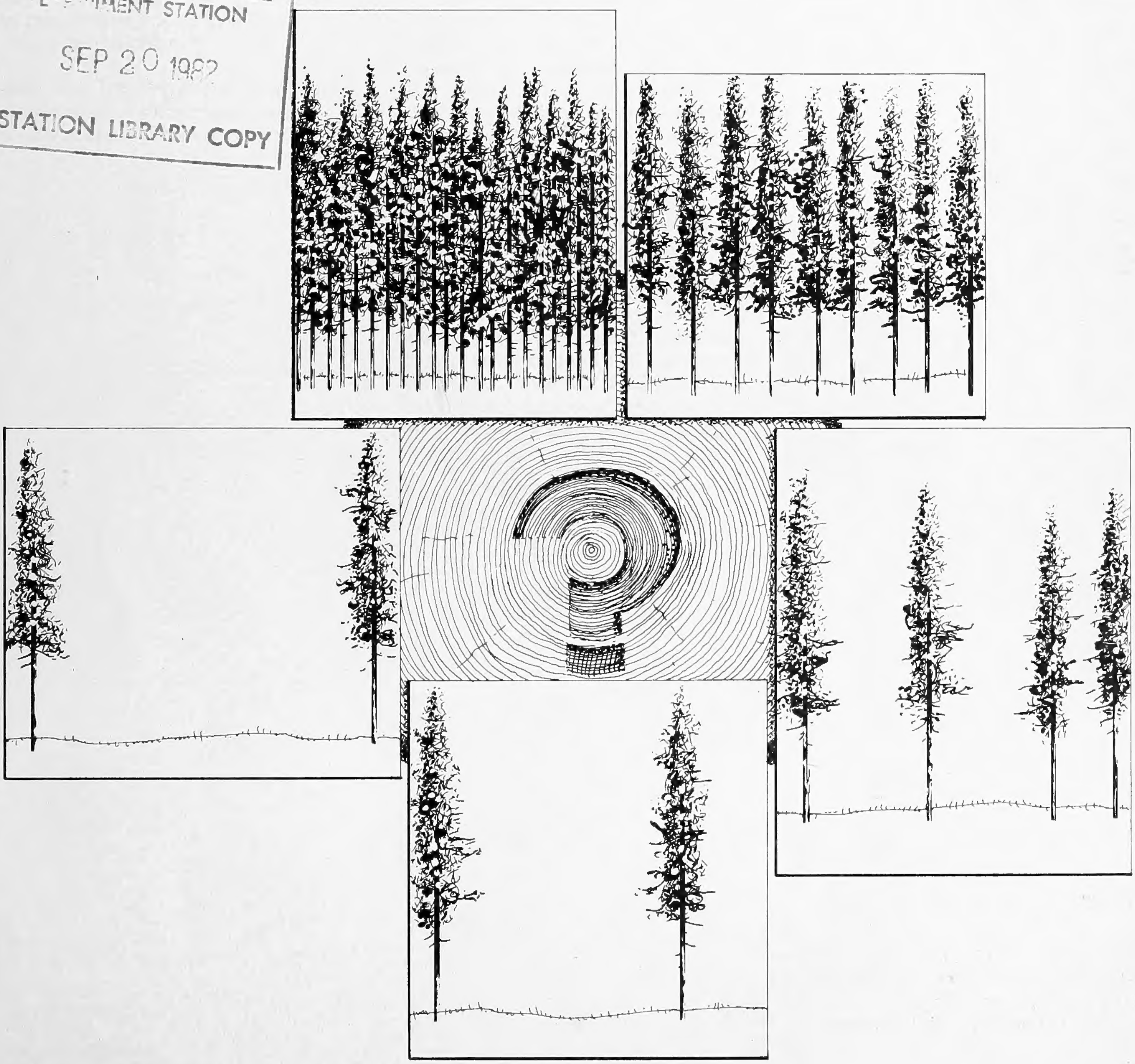

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Abstract

Barrett, James W. Twenty-year growth of thinned and unthinned ponderosa pine in the Methow Valley of northern Washington. USDA For. Serv. Res. Pap. PNW-286, Portland, OR: Pacific Northwest Forest and Range Experiment Station; 1981. 13 p.

Diameter, height and volume growth, and yield of thinned and unthinned plots are given for a suppressed, 47-year-old stand of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) in the Methow Valley of northern Washington that averaged about 3 inches in diameter and 23 feet tall before thinning. Considerations are discussed for choosing tree spacing in a precommercial thinning.

Keywords: Thinning effects, increment, stand density, improvement cutting, ponderosa pine, *Pinus ponderosa.*

Summary

Tree spacing had a profound effect on diameter, height, and volume increment in a suppressed, 47-year-old, low-site stand of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) in the Methow Valley of northern Washington that averaged about 3 inches in diameter and 23 feet tall before thinning. Trees at the widest spacing grew at an average rate per decade of 2.6 inches in diameter, compared to 1.4 inches at the narrowest spacing; trees in the unthinned plots grew only 0.4 inches per decade. Twenty years after thinning, the mean height of all trees on the low-density plot was greater than those on the high-density plot.

Although widely spaced trees grew faster in height and diameter than narrowly spaced trees, the low-density plots collectively yielded much less wood fiber than the high-density plots 20 years after thinning.

The major advantages of wide spacing in ponderosa pine in the pine-grass areas of central Washington appear to be that trees grow rapidly to merchantable size and forage production is increased.

Basal areas on unthinned plots in this study have exceeded 160 square feet per acre. These unthinned plots are now accumulating additional basal area at the rate of about 3 square feet per acre per year.

Contents

Introduction

Tree spacing of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) can have an impressive effect upon the eventual size of the trees, wood quality, the time to grow the desired product, and—frequently—the quantity and quality of the understory vegetation. Selection of spacing is one of the most significant decisions the forest manager makes, because it sets the stage for the dimensions of future harvests and interim value of other resources.

Past research has shown that widely spaced ponderosa pine trees in the Pacific Northwest maintain rapid individual tree growth longer than closely spaced trees (Barrett 1973). Wide spacing, however, is usually accompanied by losses in stand production until the area between trees is fully used.

Barrett (1971) found some evidence to suggest that stands originating on similar sites and allowed to develop full crowns will yield almost the same amount of volume over a wide range of densities. If this is true, then the question is whether the manager wants the wood in large or small trees. In most stands of ponderosa pine in the Pacific Northwest—as with many other species throughout the West—stand regulation is not that simple; stands that develop from natural seedings rarely have crowns that are free to expand. If they are widely spaced, the site is sometimes invaded by competing, brushy vegetation. In many natural stands, poor crown ratios and poor vigor are common because of high density and overstory suppression. As a result, the time to reach maximum production of useful wood is lengthened. This reduction in growth may be so subtle that the manager is unaware of the loss. Even if the loss is suspected, dealing effectively with it may be impossible because other resource values may be in jeopardy.

Research objectives in this study were:

- To provide estimates of stand growth for specified spacings, including no thinnings, for ponderosa pine in the Methow Valley.
- To compare tree growth and development of understory vegetation for the various treatments.
- To provide some interim guidelines for selecting tree spacing.

My purpose is not to suggest appropriate spacing, but by presenting results of studies on growth and spacing of ponderosa pine in the Methow Valley, to guide forest managers through the thought process of choosing the spacing compatible with their management objectives.

This study is one of several on spacing and levels of growing stock established in the Pacific Northwest in the late 1950's and early 1960's. Only the timber growth aspects of the study are included in this paper. Earlier reports on growth of timber stands were made by Barrett (1968); Sassaman et al. (1973) made an economic analysis of timber and forage returns. McConnell and Smith (1965, 1970) reported on understory responses after thinning.

The Study Area

The study area is in the upper Methow River Valley near Winthrop, Washington, on land owned and administered by the Washington State Department of Game. A combination pine-spacing and forage-production study was established in 1959 by the Washington Department of Game, U.S. Soil Conservation Service, Okanogan National Forest, and Pacific Northwest Forest and Range Experiment Station of the U.S. Department of Agriculture.

The ponderosa pine stand in which the study plots were established originated from natural seeding about 1911 after logging and fire. The stand is on a bench about 600 feet above the Methow River at an elevation of 2,350 feet (fig. 1), where precipitation averages about 14.5 inches annually. The soil is a well-drained Katar sandy loam formed from glacial till and is classified as Typic Xerochrept, coarse-loamy over sandy or sandy skeletal, mixed, mesic.

Figure 1.—The study area is on a bench in the Methow River Valley at an elevation of 2,350 feet.

The Timber Stand and Understory Vegetation

The stand in which plots were established had stagnated, with over 2,300 stems per acre, averaging only 3 inches in diameter and 23 feet high. Ten years later,the unthinned plots appeared unchanged (fig. 2). Although the stand was 47 years old, the trees were remarkably healthy and had none of the diseases common to some dense ponderosa pine stands east of the Cascade Range. Even though growth in height and diameter was slow, crowns of the dominants occupied about 50 percent of total tree height, but branches and needles were short. At the time of thinning, trees were growing only 0.6 inch per decade in diameter and 3.5 feet in height.

Estimating site index was difficult because the stand was stagnated, and density had probably inhibited height growth of dominant and codominant trees. In a nearby stand where stand dimensions appeared to be normal, as defined by Meyer (1961), site index was estimated to be site quality class V, or about 62 feet at 100 years of age.

Mortality, as evidenced by some dead stems throughout the stand, was light; only a few trees per acre died each decade. No beetle activity was evident, and mortality was attributed to gradual suppression.

Before thinning, the understory was a sparse stand of spindly shrubs and scattered forbs and grasses having a usable forage yield of only 0.06 animal unit month[1] per acre per year—" . . . a level of forage production that requires 17 acres per month or 68 acres per summer grazing season to provide the necessary forage for one cow" (Sassaman et al. 1973).

Pinegrass (*Calamagrostis rubescens* Buckl.) is the predominant grass in the area and balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.) the dominant forb (fig. 3). Scattered clumps and individual plants of antelope bitterbrush (*Purshia tridentata* (Pursh) DC.) were found throughout the stand.

[1] One animal unit month (AUM) equals 730 pounds of air-dry forage for cattle (the amount of forage consumed by a 1,000-pound animal in 30.5 days).

Figure 2.—An unthinned plot about 10 years after the study began.

Figure 3.—Wide spacing of ponderosa pine and complete slash disposal has encouraged the development of forage.

Experimental Design and Methods

The study was conducted on 13 rectangular 0.192-acre plots, 79.2 by 105.6 feet (fig. 4). Each plot is surrounded by a buffer strip 33 feet wide that was treated the same as the inner plot. The plot, therefore, contained 192 milacres and could be conveniently divided into 12 subplots, each containing 16 milacres. This plot subdivision aided in selecting leave trees that were evenly distributed throughout the plot. In addition, it easily allowed growth comparisons of the largest, evenly distributed trees within a plot.

Treatments applied to plots were thinning to average spacings of 13.2 feet (250 trees per acre), 18.7 feet (125 trees per acre), and 26.4 feet (62 trees per acre), and no thinning. Thus, each treatment contained the following measured trees on each plot:

13.2 x 13.2 feet (250 trees per acre) = 48 trees per plot;
18.7 x 18.7 feet (125 trees per acre) = 24 trees per plot;
26.4 x 26.4 feet (62 trees per acre) = 12 trees per plot.

The stand was divided into three regions with each treatment occurring in one region. The experimental design is a randomized block, split plot in time. The period effects were partitioned into orthogonal polynomial effects to look at the relations of the responses over time. One plot was thinned to an average spacing of 9.3 feet (500 trees per acre); suitable plots for two additional replications could not be found, but the single treatment is included to illustrate points in the discussion.

The 0.192-acre plots are small to represent stand growth, thus the inherent variability will be perhaps greater than might be expected. In light of the restricted scope of inference because of the limited population, results should be interpreted conservatively.

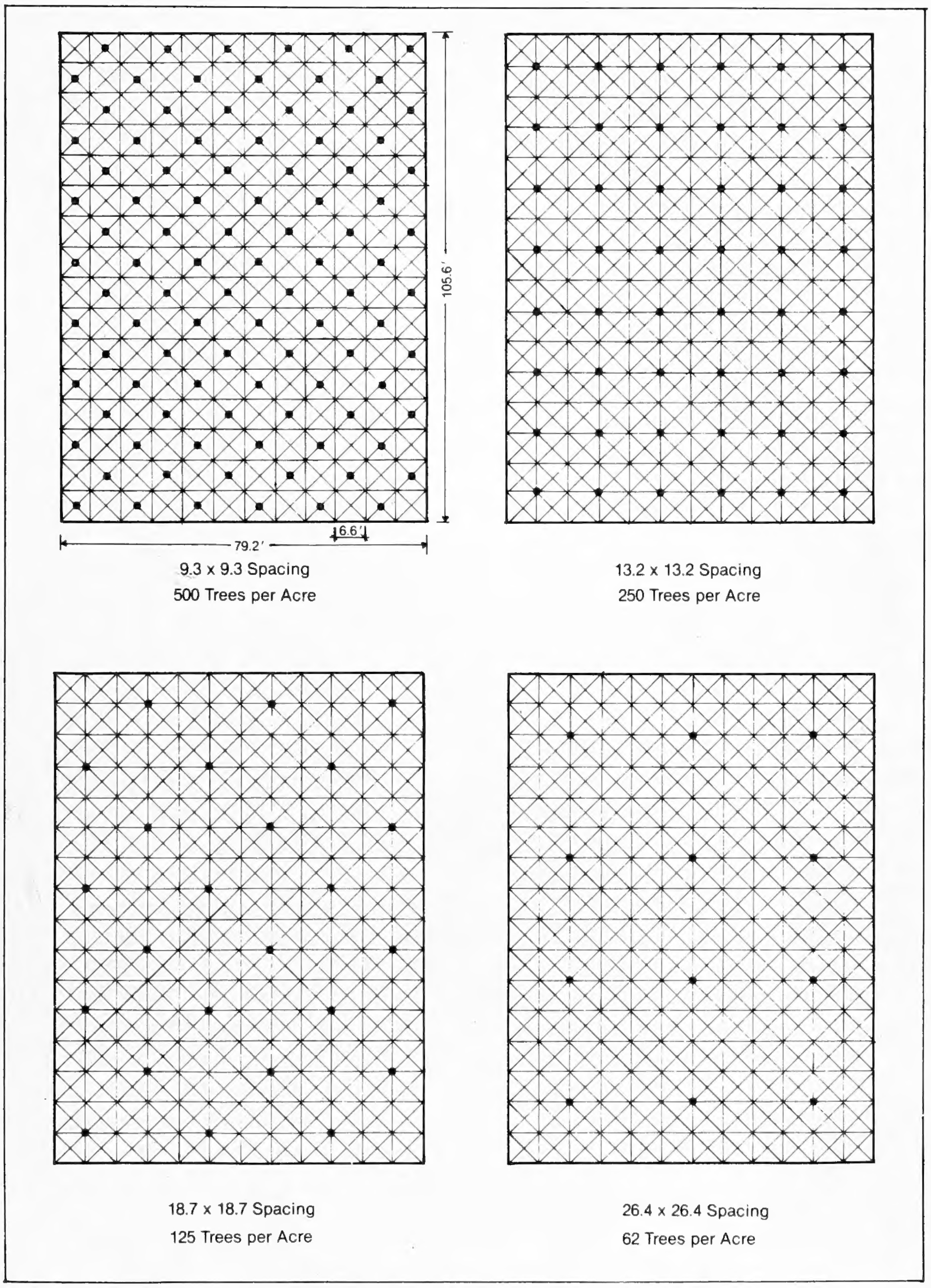


Figure 4.—Plot layout showing systematic location of trees (black dots) for a given spacing. Plots are 79.2 by 105.6 feet or 0.192 acres, containing 192 milacres (1 milacre = 6.6 x 6.6 feet). Each plot was surrounded by a buffer strip 33 feet wide that was treated the same as the inner plot. Trees were selected for thinning as close to this theoretical spacing as possible.

Results

At each measurement, all trees on thinned and unthinned plots were measured to the nearest 0.1 inch in diameter, breast high. Every tree in the thinned plots was measured, to the nearest 0.1 foot in height, with a jointed aluminum pole. Twelve trees in each thinned plot were climbed and diameter measured at 5-foot intervals up the tree. Bark thickness was measured at breast height and stump height. About 20 trees in each unthinned plot were climbed and measured. Trees were climbed that represented the complete range of diameters and heights, but sampling was heavier in the larger size classes. These trees contributed to construction of a general volume equation for second-growth ponderosa pine that was used in this study.[2] Trees on the unthinned plots were not tagged until 5 years after thinning, so no estimates of volume increment were made for the unthinned plots during the first 5 years. Periodic measurements were made initially and then every 5 years for 20 years.

Note that data from the treatment that left 500 trees per acre were from only one plot (compared to three plots for the other treatments).

[2] "Volume equations for second-growth ponderosa pine in the Pacific Northwest," by Donald DeMars and James W. Barrett. Manuscript in preparation.

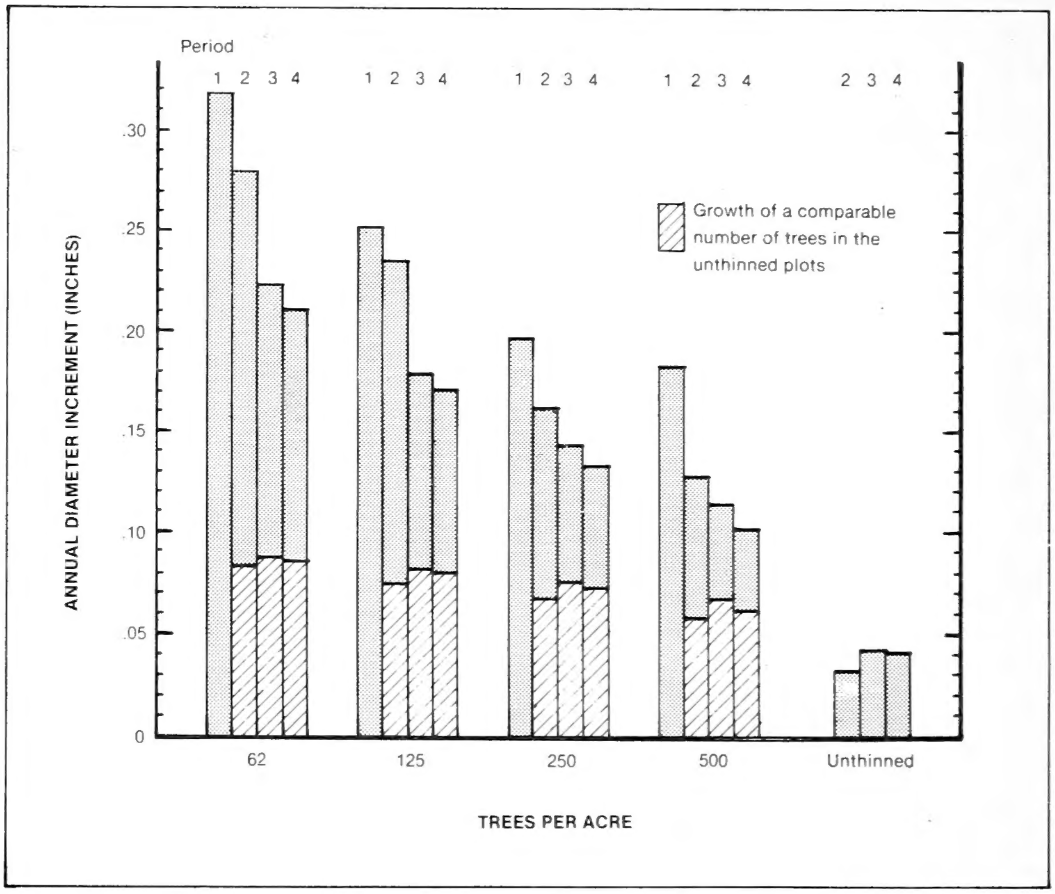


Figure 5.—Average annual diameter increment of ponderosa pine during the first, second, third, and fourth 5-year growth periods after thinning, and growth of a comparable number of trees in the unthinned plots.

Diameter Growth and Average Diameter

Widely spaced trees in the thinned plots grew significantly better in diameter (table 1) than closely spaced trees (fig. 5). Trees at the widest spacing grew at an average rate per decade of 2.6 inches compared to 1.4 inches at the narrowest spacing.

In comparison, trees in the unthinned stand averaged only 0.4-inch growth per decade. In 1978, the unthinned plots were divided on the ground by strings into 12, 16-milacre subplots as shown in figure 4. Growth of the "best" trees—those that would be selected for leaving in a precommercial thinning—were examined. All trees in the unthinned plots were tagged in 1964, so growth could be determined from this date through growth periods 2, 3, and 4. Tag numbers of 12, 24, 48, and 96 trees per plot were chosen. First, for example, the 12 best trees per plot—one for each 16-milacre subplot—were chosen, and their tag numbers recorded. Then the next best 12 trees were selected, or two per subplot, and so on. Appropriate tree numbers and dimensions were run on the computer to calculate growth of trees and plot averages.

This analysis, where average annual growth in diameter of the 12 best well-distributed trees per plot (62 trees per acre) were compared with the 96 best trees per plot (500 trees per acre), showed only a 0.03-inch difference (fig. 5). Even the best dominants in the stand are suffering from severe competition. Such a small difference occurred from one extreme of tree density to another that no statistical test was done.

Table 1—Results of analysis of variance[1]

Variable	Blocks	Spacing	Periods: Linear[2]	Periods: Quadratic[3]	Lack of fit[4]	Spacing x period interaction
Diameter increment	n.s.	**	**	**	n.s.	**
Height increment	n.s.	**	**	**	n.s.	n.s.
Volume increment	*	*	**	n.s.	**	**
Basal area increment	n.s.	**	n.s.	n.s.	n.s.	**
Diameter	**	**	**	**	**	Linear**
Height	**	**	**	*	*	Linear**
Volume	**	**	**	n.s.	*	Linear**
Basal area	**	**	**	n.s.	n.s.	Linear**

[1] Symbols are: n.s. = not significant; * = significant, 5 percent level of probability; and ** = significant, 1 percent level of probability.
[2] "Linear" isolates the variation accounted for if a straight line is fit through the data points.
[3] "Quadratic" isolates the variation accounted for if a second degree curve is fit through the data points.
[4] "Lack of fit" isolates additional variation not accounted for by linear and quadratic.

Rate of growth in diameter has declined[3] within thinned treatments throughout the 20 years of observations (fig. 5), although, as discussed later in the paper, basal-area increment has remained rather stable. Diameter growth at the widest spacing (26.4 feet) has dropped from an annual rate of 0.32 inch during the first 5 years to 0.21 inch during the last 5 years. The percentage decrease appears to have diminished during the last decade compared to the first; i.e., the great flush of growth after thinning may be subsiding.

Twenty years after thinning, average diameter of the stands thinned to 62 trees per acre is 11 inches compared to 7.5 inches where 250 trees per acre were left (fig. 6).[4] Also, note that 20 years after thinning, most are from 9 to 13 inches where 62 trees per acre were left and from 5 to 9 inches where 250 trees were left

[3] The significant interaction between spacing and linear periods indicate that this decline is not consistent from treatment to treatment.

[4] These curves of diameter (fig. 5), height (fig. 7), basal area (fig. 8), and volume (fig. 11) plotted over periods of time illustrate the regression equations fitted through the data sets. The main effects of spacing were significant for all of these response variables. The interaction effect of spacing by linear period was also signficiant for all response variables, indicating the curves differ in their slope.

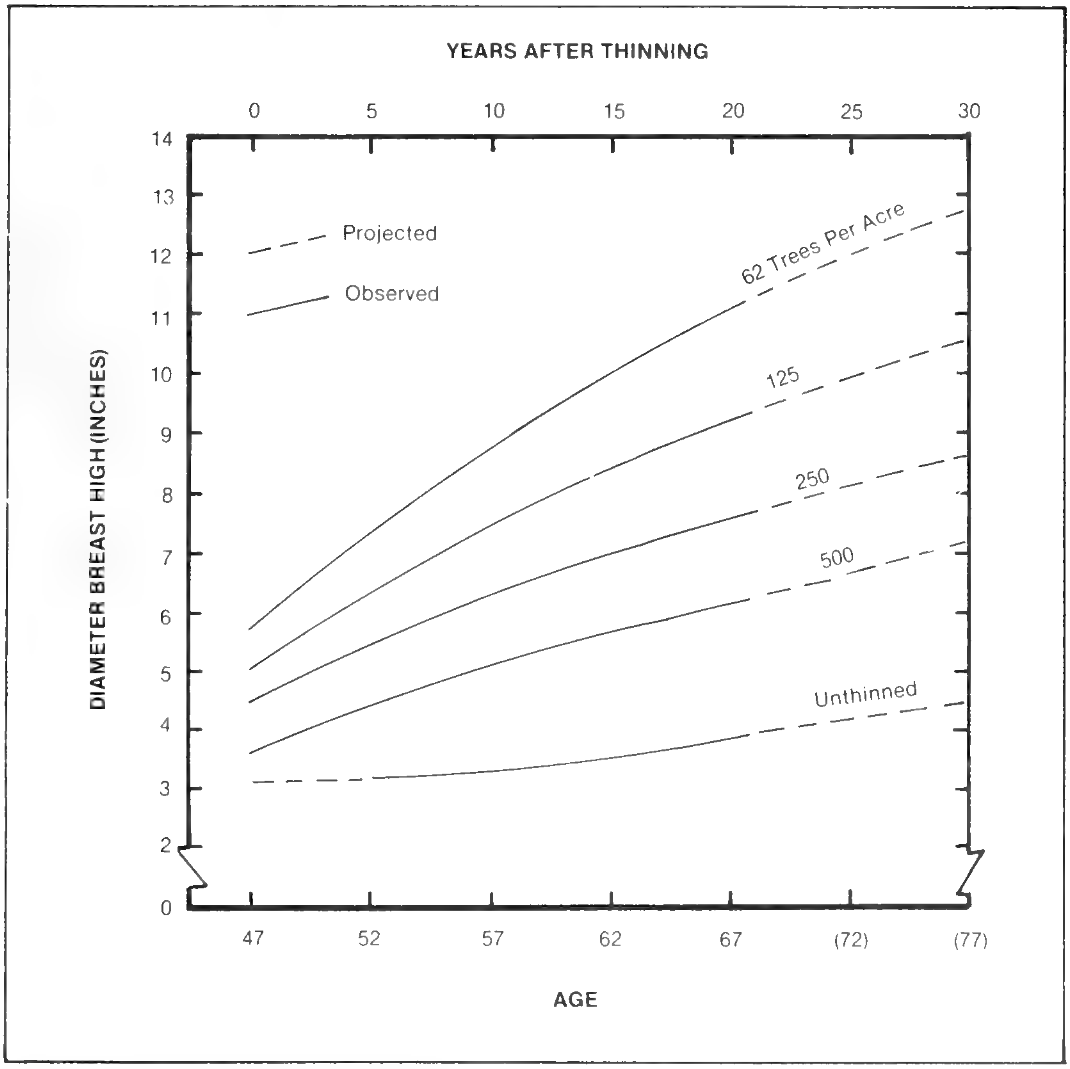


Figure 6.—Average stand diameter under various treatments during the 20 years of observation and estimates projected 10 years in the future.

Table 2—Number of trees in each diameter class at the beginning and end[1] of the observation period

Diameter class	Thinning treatment—trees per acre: 62		125		250		500		Unthinned	
	Start	End	Start	End	Start	End	Start	End	Start	End
Inches	*Trees per acre*									
1					2				451	281
2			4		15	2	125		804	621
3	1		14		47		198	10	577	548
4	14		36		94	10	136	84	307	375
5	19		38	2	59	17	31	125	150	213
6	9	1	23	7	28	38	5	115	57	134
7	14		3	14	2	56		104	24	42
8	5		3	26	3	63	5	47	10	26
9		10	2	28		49		10	5	12
10		14	2	33		10				9
11		12		5		3				2
12		14		5				5		
13		7		2						
14		2		3						
Total	62	60	125	125	250	248	500	500	2385	2263
Average[2] d.b.h.	5.8	11.1	5.1	9.2	4.4	7.6	3.4	6.1	3.1	3.6
Basal area	11.4	40.3	17.4	57.7	26.8	77.9	32.4	100.7	122.2	164.4

[1] The stand was 47 years old at the beginning and 67 years old at the end of the observation period.
[2] Quadratic mean diameter.

(table 2). A wide range of diameters occurred where 125 trees per acre were left. Effects of spacing are somewhat confounded by initial differences in size. Denser spacings were somewhat poorer initially than unthinned. Also, when trees to be left were chosen, initial diameters for each treatment were larger as tree spacing increased. For example, initial diameters at age 47 were as follows:

Trees per acre	Spacing	Diameter breast high
Number	*Feet*	*Inches*
62	26.4	5.8
125	18.7	5.1
250	13.2	4.4
500	9.3	3.4
Unthinned		3.1

Diameters are projected to 30 years after the initial thinning.[5] Although commercial thinning at age 77 would seem doubtful, it may be possible in the two widest spacings. Average diameters at this time are estimated to be (fig. 6):

Trees per acre	Diameter breast high
Number	*Inches*
62	12.7
125	10.5
250	8.6
500	7.1

Even though some trees are merchantable where 62 and 125 trees per acre were left, there is little reason to thin. Trees are growing well in diameter and height, and basal area is well below the risk level for bark beetles. A thinning at this time in the two closer spacings is probably not practical, because diameters are too small.

Height Growth

Released trees in this study required about 15 years to reach their maximum rate of growth in height (fig. 7). During this time, height growth gradually increased in trees on each thinned treatment; during the fourth growth period (15 to 20 years after thinning), however, rates decreased for all thinned densities. This may have been caused by serious drought, although diameter growth did not decrease markedly during the last period.

Spacing significantly affected height growth (table 1). For example, during the third 5-year growth period, trees at the lowest density grew about 1.25 feet per year, but only 0.7 foot at the highest density. The effect of density on height growth of the 62 trees of largest diameter across all spacings is questionable (fig. 7). A trend of reduced height growth with increasing density is suggested, but was not tested statistically because of study design, within-treatment variation, and the slight difference in height growth between the two densities fully replicated. All trees in the unthinned stand were estimated to have averaged only about 0.2 foot of height growth per year.

Twenty years after thinning, considerably taller trees are present on low-density plots than on higher-density plots. For example, trees averaged almost 50 feet tall at the widest spacing 20 years after thinning and about 39 feet where 250 trees per acre were left (fig. 8). Average heights of these trees 30 years after thinning are estimated to be about 65 and 45 feet, respectively. Note that when leave trees were selected in the precommercial thinning, the average initial height of the stand (means of field data) increased as spacing increased; for 500, 250, 125, and 62 trees per acre, they were 18.6, 23.5, 25.7, and 28.4 feet.

The limited sample of heights did not permit a reliable picture of individual height increment on the unthinned plots, so this is not shown in figure 7. Average height of unthinned plots shown in figure 8 is based on the relation of height to diameter of about 20 measured trees on each unthinned plot.

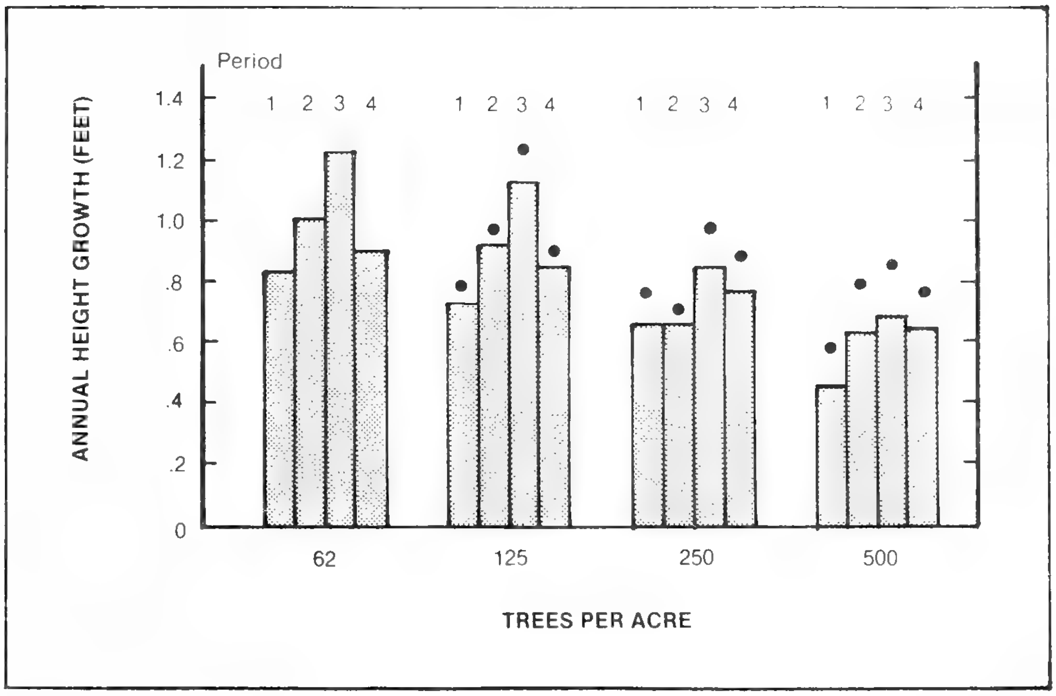


Figure 7.—Average annual height growth during the first, second, third, and fourth 5-year growth periods since thinning. Dots above bars indicate growth of the 62 largest diameter trees.

Height growth declined during the last measurement period (fig. 7), therefore the curves of average height with time shown in figure 8 should also decline. Note, however, that the relationships shown in figure 8 represent curves that estimate maintaining the present rate of height growth for a decade. I would not expect a marked decline in height growth at this stage of stand development, except from some short, periodic climatic influence.

[5] Projections of tree diameter, height, and stand volume beyond 20 years after thinning were made by equations fitted to the data and by examining trends of periodic diameter and height increment. Unforeseen climatic changes during the next decade could influence these estimates.

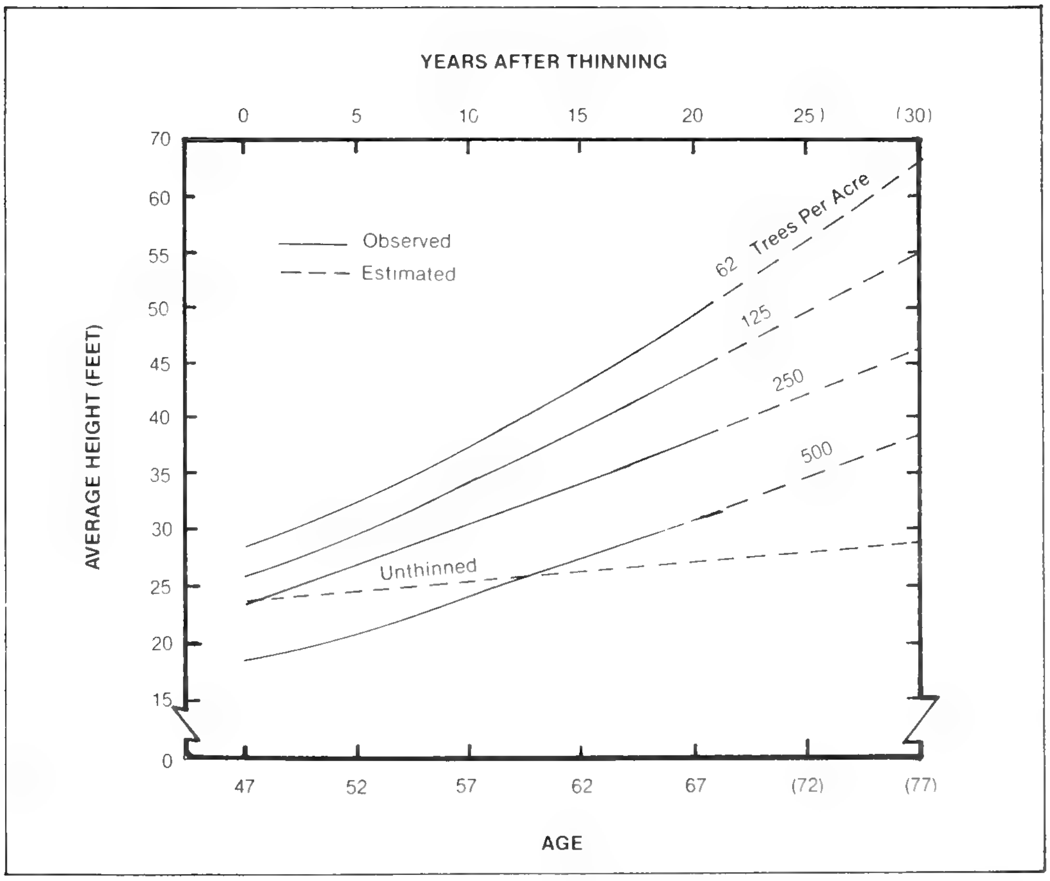


Figure 8.—Average tree height under various stand densities during 20 years of observation, and estimates projected 10 years in the future.

Basal Area

Accumulation of basal area is important in thinned stands, but it is also of concern in unthinned stands, because it gives us a clue to excessive density that may be conducive to beetle attack (Sartwell 1971). The unthinned plot in this study has some characteristics of a stand subject to mountain pine beetle attack, because it now has over 160 square feet of basal area per acre (fig. 9) and is accumulating additional basal area at about 3 square feet per year (fig. 10). Trees are growing slowly because of competition, they are on a low site, and they are about the right size for development of insect broods.

Basal-area increment was significantly and positively correlated with spacing (table 1). Basal area is accumulating at the rate of about 1.5 square feet per acre per year at the lowest density and about 3.25 square feet where 500 trees were left (fig. 10). The greater the growing stock the greater the basal-area increment in the thinned stands. Note that the stand thinned to 500 trees per acre now has 100 square feet per acre. In 10 years, this plot will have over 130 square feet.

The odd high basal-area increment during the first period where 500 trees per acre were left (fig. 10) may result from the exceptional response of some of the larger trees directly after thinning. A decided decrease in growth in these same trees took place during the second period, when competition from other trees probably had an effect.

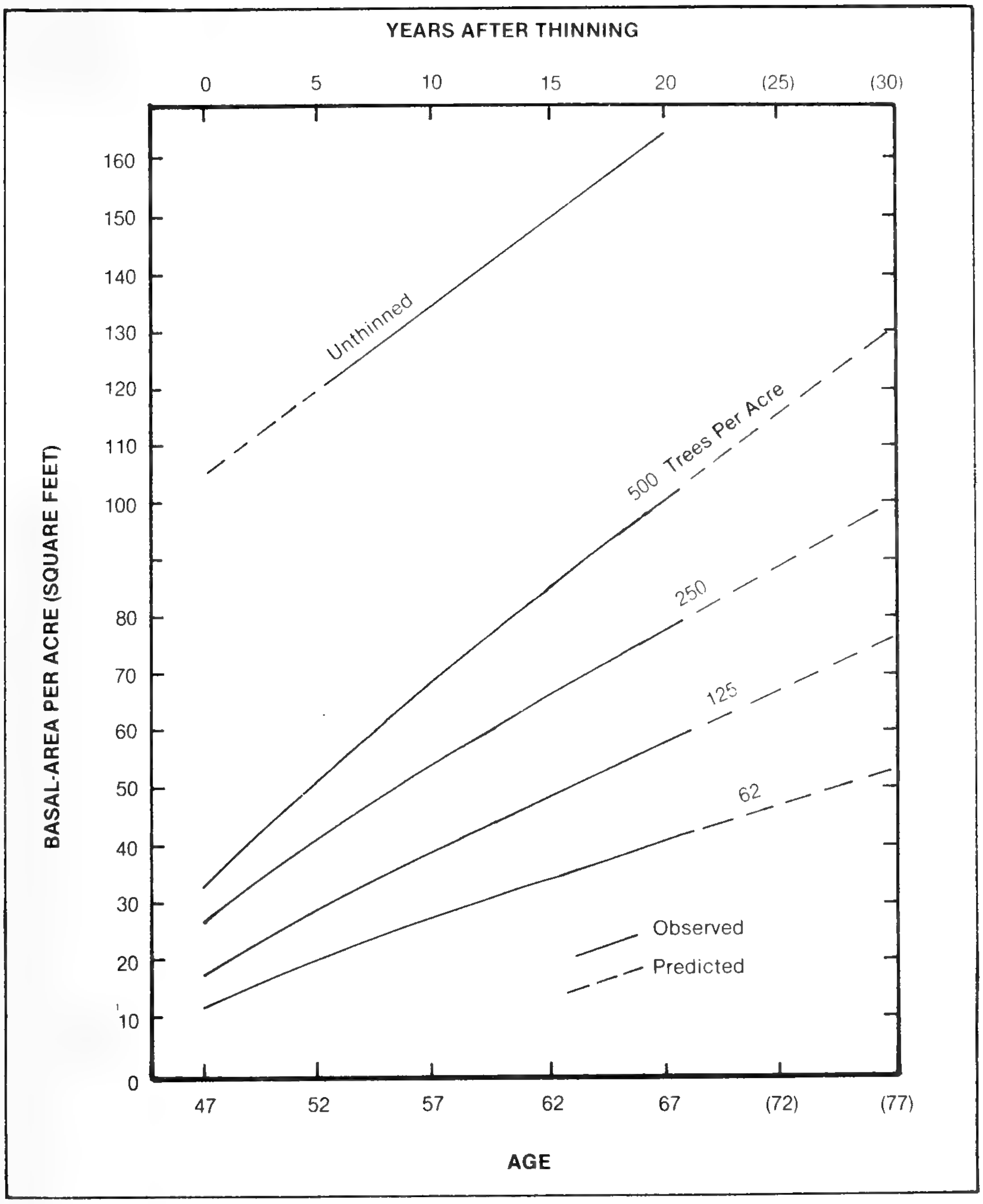


Figure 9.—Net basal area attained during the first, second, third, and fourth 5-year periods, and predicted values 10 years in the future.

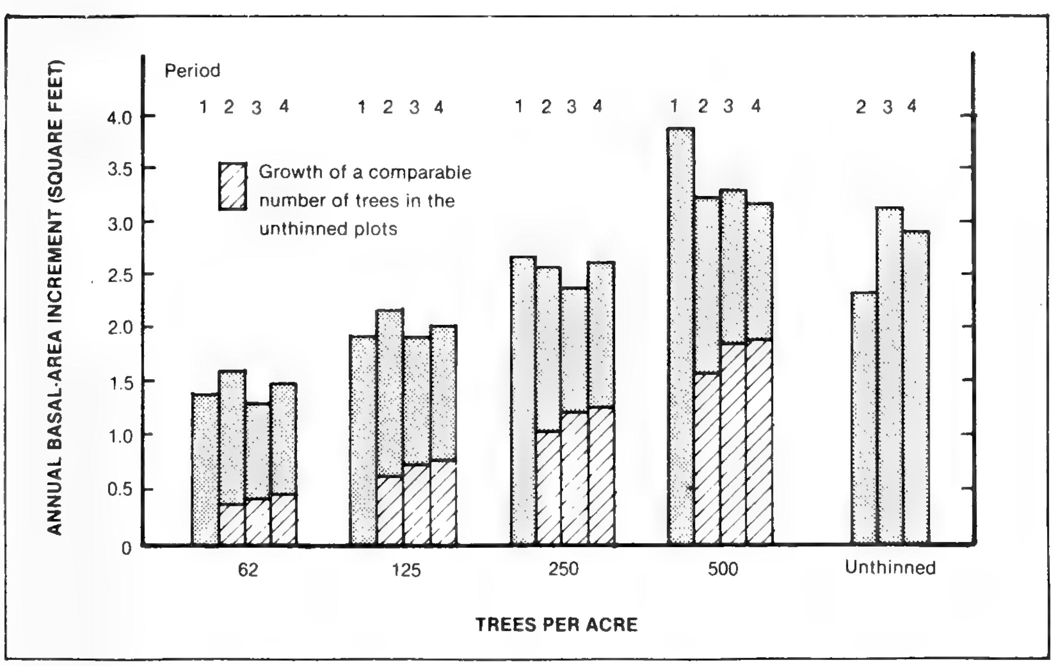


Figure 10.—Average annual net basal-area increment of ponderosa pine during the first, second, third, and fourth 5-year growth periods after thinning, and increment of a comparable number of trees in the unthinned stand.

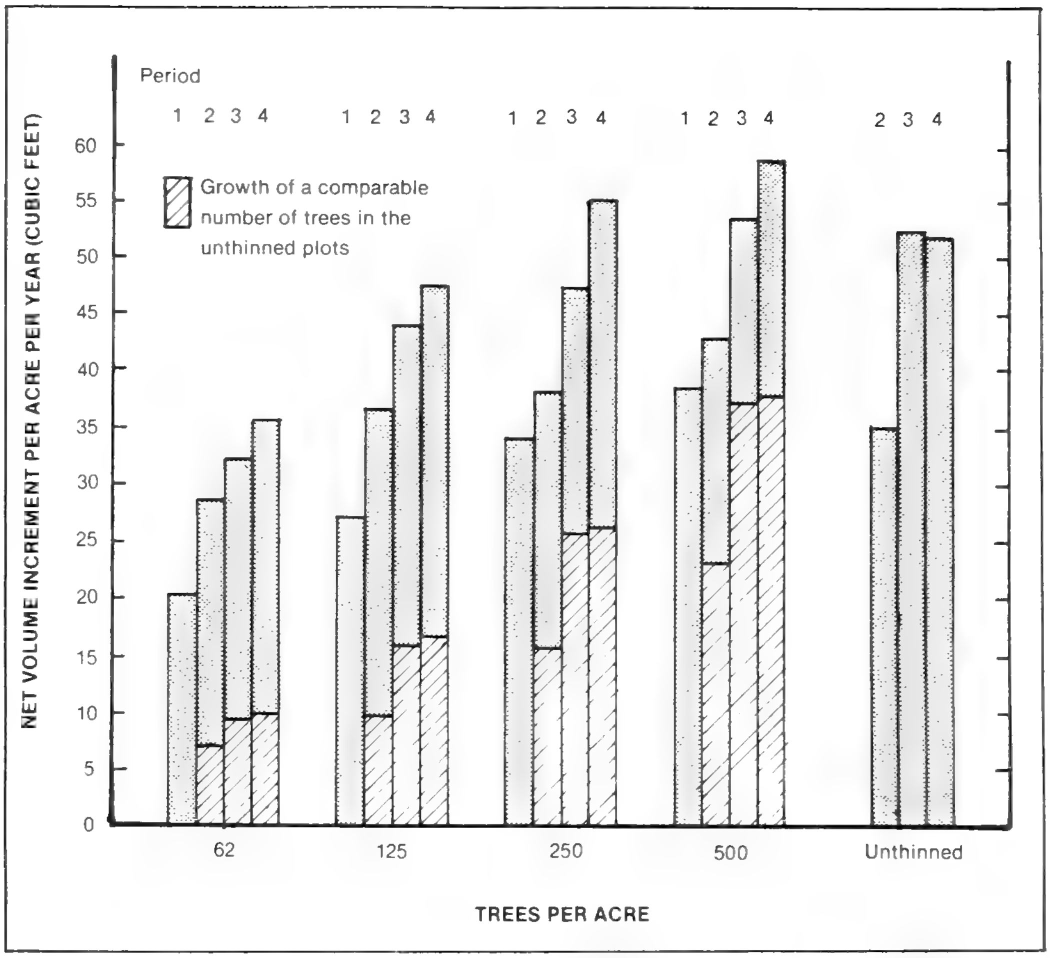
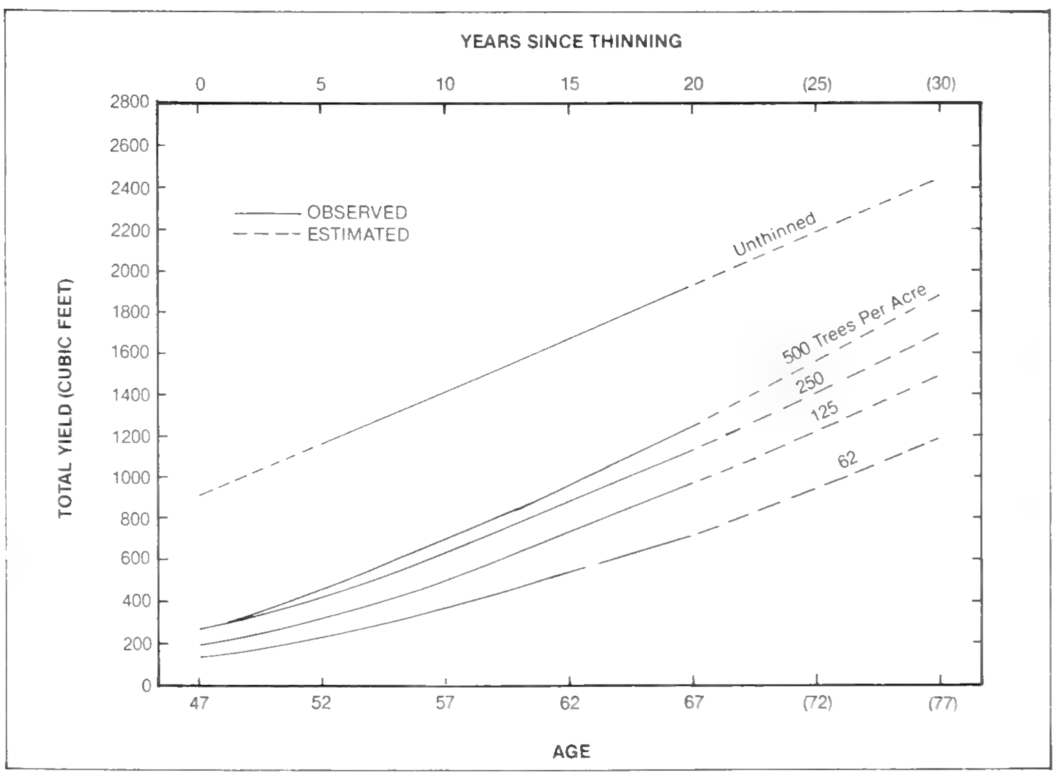


Figure 11.—Average annual net cubic-volume increment of ponderosa pine during the first, second, third, and fourth 5-year growth periods, and increment on a comparable number of the best well-distributed trees in the unthinned stand.



Volume Increment and Yield

The effect of spacing on volume increment was significant (table 1). Periodic volume increment also showed a trend toward increase with time in all thinned treatments (fig. 11). Trees on plots at various densities of 62, 125, 250, and 500 trees per acre produced 62, 92, 107, and 114 percent of the volume produced by the unthinned plots during the last period. This annual increment will probably increase until maximum capacity for growth for a given density is reached.

The larger, dominant trees in the unthinned stand are not contributing much volume increment. For example, the 125 largest trees in the unthinned stand produced only 16 percent of the volume grown by all the trees in the unthinned stand (fig. 11), indicating that even the dominants are suffering severe competition from other trees in this natural, dense stand.

Although the unthinned stand presently contains the highest amount of wood fiber (fig. 12), the volume is distributed on trees that have an average diameter of a little less than 4 inches. Compare this to trees at the widest spacing that now average 11 inches in diameter.

The relation of volume increment to stand density for ponderosa pine, over a range of sites and plant communities in the Pacific Northwest, needs to be determined. As a beginning, volume increment related to basal area and stand-density index (SDI) (Reineke 1933)[6] in this study are presented in figures 13 and 14.

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[6] Personal communication with Donald DeMars, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

DeMars computed the basic Reineke type equation $\text{Log}_{10}\,\text{TPA} = 4.32807 - 1.76533\ \text{Log}_{10}\,\text{DBH}$ from plot data accumulated by Meyer (1961) for ponderosa pine. Thus: $\text{Log}_{10}\,\text{SDI} = \text{Log}_{10}\,\text{TPA} - 1.76533 + 1.76533\ \text{Log}_{10}\,\text{DBH}$, where
SDI = stand density index;
TPA = trees per acre;
DBH = average diameter of stand.

Figure 12.—Net yield of ponderosa pine thinned to densities of 62, 125, 250, and 500 trees per acre and of the unthinned stand.

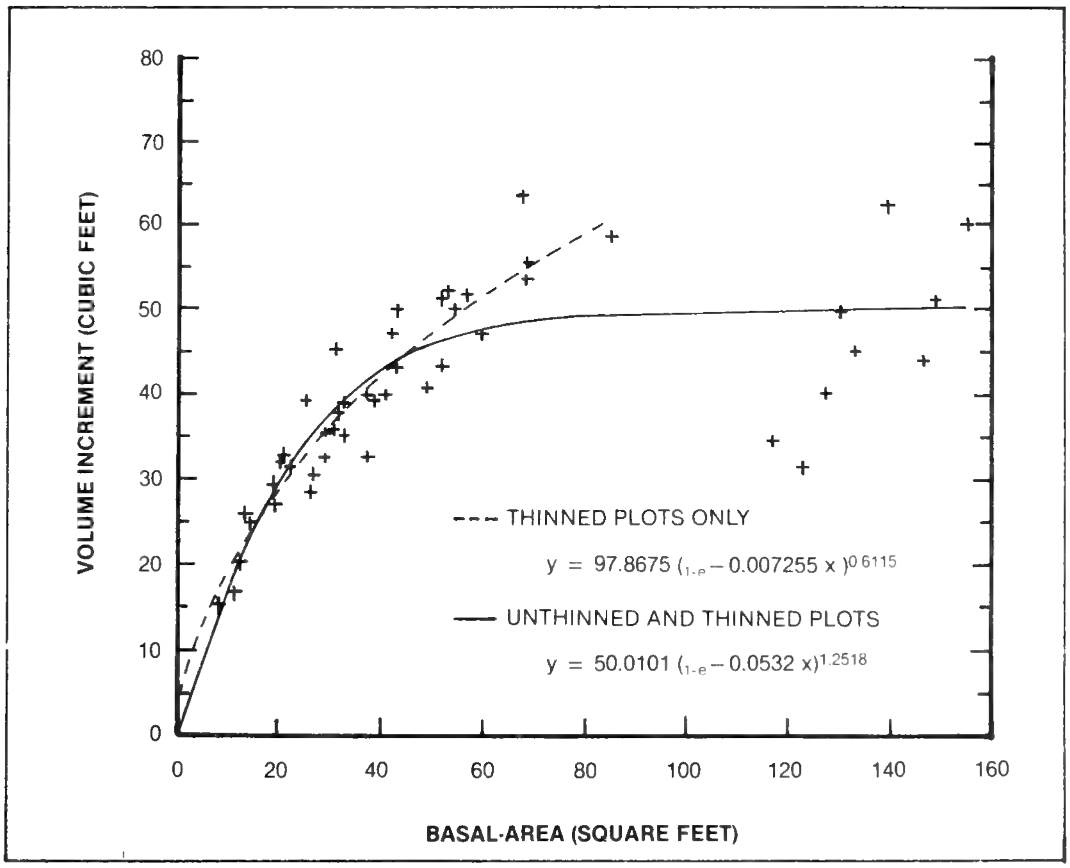

Figure 13.—The relation of annual volume increment to initial basal area. Each point on the figure represents the periodic volume increment relative to basal area for a plot at the beginning of the 5-year period.

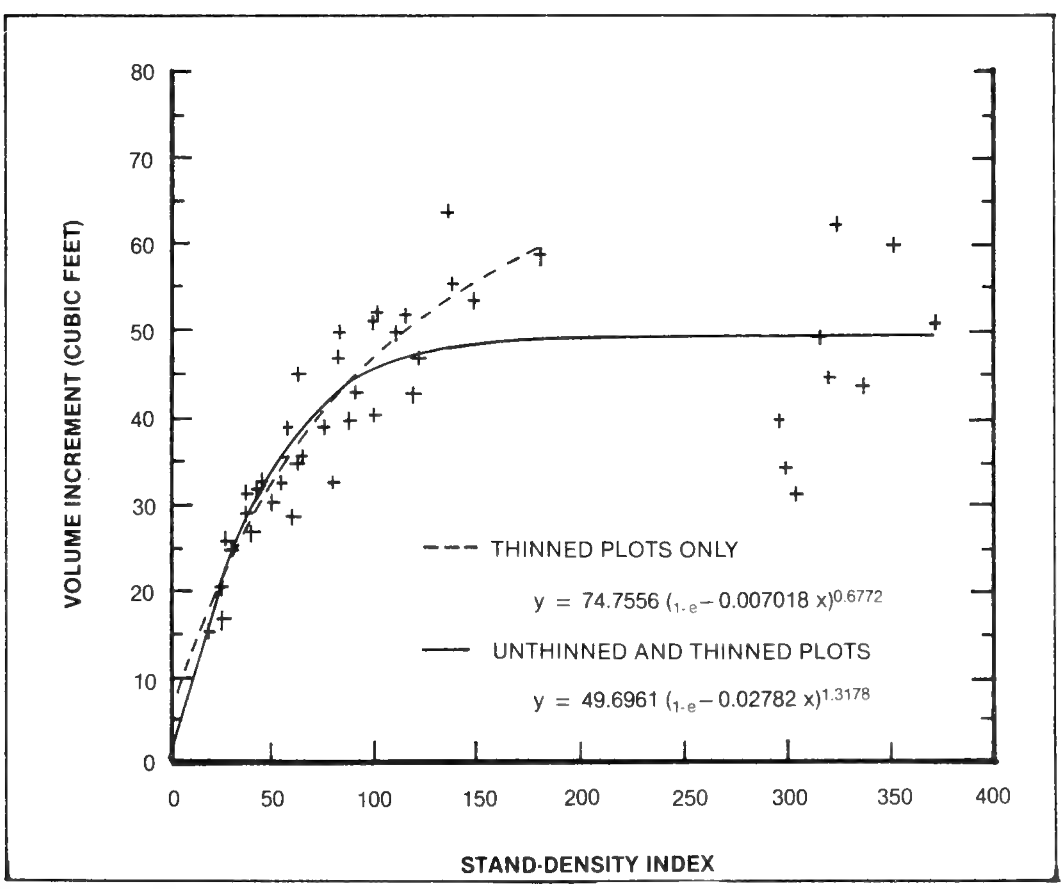

Figure 14.—The relation of annual volume increment to initial stand-density index (Reineke 1933). Each point on the figure represents the periodic volume increment relative to the stand-density index of a plot at the beginning of the 5-year period.

Discussion and Application

Mortality

Only two trees of 348 died on the thinned plots in 20 years of observation. One tree died in the 250-tree-per-acre treatment and one where 125 trees per acre were left. This is a loss in yield of about 6 and 9 cubic feet per acre. Both trees died 10 to 15 years after thinning.

On the three unthinned plots, 70 trees of 1,374 died during the last 15 years of observation. Most trees were less than 2 inches in diameter, but occasionally, a 3- or 4-inch tree died. Only intermediate or suppressed trees died, and mortality accounted for less than 3 percent of gross annual increment on a plot for any one period and averaged 1.5 percent. Thus, mortality had a minor influence on increment and yield in the unthinned plots and practically no effect on the thinned plots.

Applying quantitative data from a study of this kind to similar sites on different soils and plant communities is tempting, because they may be the only data available. If this study were replicated in other places in northern Washington and results were consistent, the geographical and quantitative inference could be expanded; with only one installation, conservative application is appropriate.

Much can be gained from this study by looking at the magnitude of the effects of spacing and tree selection on growth and eventual yield, rather than applying quantitive results. The study provides actual data on wood-volume production of thinned stands in this part of Washington. It also provides a clue as to the time needed to grow trees to commercial sawlog size.

Mortality figures for managed and unmanaged stands are compared. The study also adds strength to the concept that mortality in thinned, ponderosa pine stands is minor during the first 20 years after thinning. Past experience suggests that when mortality is major, it is usually catastrophic—from wildfire or insects. Unthinned sapling stands in the area are now growing rapidly into overdense, small-pole stands that could be subject to insect attack if left unthinned.

Spacing affects the size of products produced, their quality, and the cost of harvesting the wood. In most areas, spacing of ponderosa pine can also have a profound effect on the development of understory vegetation (McConnell and Smith 1970, Barrett 1973). Leaving excessive numbers of trees in an initial thinning to allow for mortality and prepare for a highly questionable round-wood market may not be the logical approach in this area. Evidence from this study and others in Oregon indicate little mortality occurs in healthy, thinned stands. Also, lower density stands enhance the production of forage for game and red-meat production, which is important in north-central Washington. Leaving too many trees will prevent the stand from attaining the size necessary for sawlog marketability and may necessitate another costly precommercial thinning.

Thinning dense stands of ponderosa pine results in a temporary loss in the total capacity of the timber site to produce wood fiber, but the thinning is usually needed to produce a salable product. After a stand is thinned, time is needed for the remaining live tree roots to grow and invade the soil formerly occupied by the trees that were cut. The greater the spacing distance, the greater the time needed to occupy the space between trees with roots and crown. Final yield can be notably reduced as a consequence of excessive spacing. But this sacrifice in production early in the rotation can sometimes be justified by the objectives of resource management.

Managers in north-central Washington might consider the following points in selecting a spacing. If 500 trees per acre is the highest density that will be considered, then we may examine the consequences of further density reduction. From figure 15, we find that total cubic yield in the Methow study 20 and 30 years after thinning falls off slowly as density is lowered to 250 trees per acre, but it falls more rapidly with further density reduction. For example, I estimate a loss of about 10 percent in yield at 30 years after thinning from 500 trees per acre to 250. But this loss reaches about 21 percent if trees are reduced to 125. If the objective is a commercial thinning of sawlogs in the shortest time, wider spacing offers a distinct advantage in product size. Trees at 125 trees per acre would have an average diameter of about 10.5 inches 30 years after thinning, compared to only 7.1 inches if 500 trees were left (figs. 6 and 15). Even with the impressive reduction in yield by going to the wider spacing, note that—during the last period—plots thinned to 125 trees per acre grew almost 81 percent of the volume increment grown where 500 trees per acre were left (fig. 11). During the next decade, 125 trees per acre might produce as much volume annually as 500 trees per acre. From figures 6, 8, 12, and table 2, various combinations of yield and product size can be estimated. These estimates thus provide an interim guide for spacing selection. Alternatives for producing various wood products should eventually be examined using an appropriate stand-growth simulator for ponderosa pine. Such a simulator is now being developed at the Pacific Northwest Forest and Range Experiment Station.

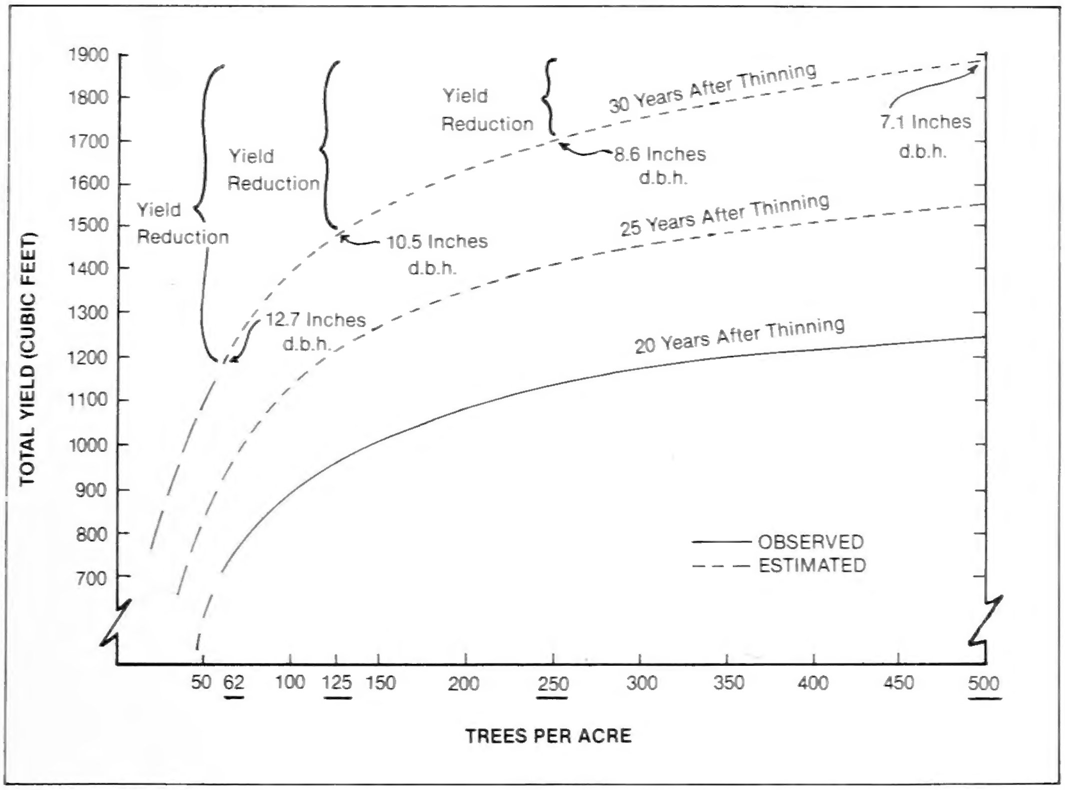

Figure 15.—Yield of ponderosa pine 20, 25, and 30 years after thinning to various tree densities.

Choice of initial spacing on public land is usually not based on wood yield alone. Many thinned stands are also potential sources of forage for big game and livestock. McConnell et al.[7] found substantial increases in forage production at the wider spacings in the study reported here. Thus, even though the wider spacing temporarily reduced production of wood fiber, it increased the potential for production of red meat, with possibly a greater resource appeal than for wood alone. As shown in figure 6, 12-inch sawlogs might be produced in 30 years by leaving only 62 trees per acre. Low tree-density may be an appropriate practice on some deer winter ranges where maximum forage production is the principal concern.

[7] Response of understory vegetation to ponderosa pine thinning in eastern Washington, by Paul J. Edgerton, Burt R. McConnell and Jon M. Skovlin. Manuscript in preparation.

Finally, I would like to stress that this study was made in a typical stagnated stand of ponderosa pine on a poor site. Precommercial thinning should have been done much earlier, but trees responded quickly and well to such late release. Apparent gains from the thinning are impressive, because the alternative of stagnation offers little hope of useful wood production for many years.

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.3048 meter
1 acre = 0.405 hectare
1 square foot/acre =
  0.2296 square meter/hectare
1 cubic foot/acre =
  0.06997 cubic meter/hectare
1 tree/acre = 2.471 trees/hectare

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Diameter, height and volume growth, and yield of thinned and unthinned plots are given for a suppressed, 47-year-old stand of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) in the Methow Valley of northern Washington that averaged about 3 inches in diameter and 23 feet tall before thinning. Considerations are discussed for choosing tree spacing in a precommercial thinning.

Keywords: Thinning effects, increment, stand density, improvement cutting, ponderosa pine, *Pinus ponderosa.*

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